Seba, Albertus
1758. Locupletissimi rerum naturalium thesauri accurata descriptio. Amsterdam, vol. 3

Stoll, Norman Rudolph *et al.*
1961. International code of zoological nomenclature adopted by the XV International Congress of Zoology. London xviii + 176 pp.

Thiele, Johannes
1931 - 1935. Handbuch der systematischen Weichtierkunde. Jena, pp. 1 - 1154; 893 text figs.

Tomlin, John Read le Brockton
1944. Deshayes' review of *Terebra*. Journ. Conch. 22 (5): 104 - 108 (30 November 1944)

Weaver, Clifton S.
1960 - 1961. Hawaiian marine mollusks; the genera *Terebra* and *Hastula*. Insert in Hawaiian Shell News 1 (1 - 9): 1 - 36; plts. 1 - 9 (1 January 1960 to 1 January 1961)

Wood, William
1828. Index testaceologicus or a catalogue of shells, British and Foreign, arranged according to the Linnean system. 2nd. ed., London, Vols. 1 - 2; 46 col. plts.

Elevation of Clams in Coral Sand

BY

JACK T. TOMLINSON

Biology Department, San Francisco State College
San Francisco, California 94132

Armstrong (1965) has found that some clams of the larger species with long, extensible siphons, do not seem to be able to elevate, or come up through the sand. His experiments included covering the clams with additional sand from their environment. Until a critical amount {four inches of additional sand for *Tresus nuttalli* (Conrad, 1837), three inches for *Protothaca staminea* (Conrad, 1837)} was added, the clams could extend their siphons and/or maintain a conical depression in the surface of the sand, and survive. At this critical level all clams succumbed. Removal and redeposition of sand did not kill the clams, so that it was not just 'suffocation' from the disturbed sand that caused the deaths, but the inability of the clams to elevate through the sand or to extend their siphons.

It is known that clams are less dense than their environment. Armstrong's clams average 1.21 to 2.04 in specific gravity (gm/cc), while local inorganic sands average 3.00. The average of the ten species tested was 1.46 gm/cc, less than half that of the sand. The effect of this difference in specific gravity would be to cause the clams to be buoyant in the sand, and any motion on their part would tend to lift them up through the sand. Thus, their main efforts in areas of sand agitation through surf action would be to remain submerged, and their capabilities are morphologically and physiologically directed toward this end. If wave action is not sufficient to disturb the sand sufficiently to elevate the clams, it would be possible for them to 'shake' themselves and elevate to a limited extent, provided that they are not buried too deeply or the sand is not too compact. The tendency for the relatively fine sand to be sifted under larger objects would also cause sand agitation to effectively lift the clams out of the sand. The application of this buoyancy and sifting effect can be readily seen by shaking a container with sand and clams, where one will see the latter lifted completely out of the sand even if dead. If 'quicksand' is artificially produced by forcing sea water up through the sand, the clams come immediately to the surface and cannot re-enter the sand.

While on Heron Island, Queensland, Australia, I encountered the clam *Actactodea mitis* Deshayes [=*A. striata* (Gmelin)] (ident. Tom Iredale). It was burrowing with its hinge line up and parallel to the shore in the wave zone of the coral sand beaches. The sand had a specific gravity of 2.86, while the clam's was 2.01, both measured by weighing them dry and determining the volume by water displacement. The clams were collected above the water line, averaged 21.6 mm in greatest diameter, and were wiped dry with a cleansing tissue. Clams with the same size distribution (to the nearest mm) collected *below* the water line had a specific gravity of 2.07,

presumably due to the retained water rather than air space in their mantle cavity.

When covered with one-half inch of sand or less at intervals of about 20 minutes, 50 of 150 clams elevated nine inches in six hours; when $1\frac{1}{4}$ to $1\frac{1}{2}$ inches of sand was added at hourly intervals, of 50 clams only 1 clam elevated three inches in 12 hours, two raised themselves two inches, and the rest stayed in place. Both sets were allowed to rebury after the counting to check for weak or dead clams. There were two and one individuals, respectively, who did not respond by reburying themselves.

The clam has a very short siphon. It lives just beneath the surface of the sand, with the siphon extending into the water. It possesses an obvious ability to elevate itself in the sand. It is to be noted that the difference between the specific gravity of *Actactodea mitis* and the coral sand is considerably less than that between ARMSTRONG's species which could not elevate themselves, and their inorganic sand. Perhaps clams in coral sands cannot depend on buoyancy to elevate them to the extent that clams can in inorganic sands, and thus tend to have mechanisms which enable them to actively elevate themselves in the sand.

The clams were placed between two glass plates, with native sand, allowed to burrow below the surface, and then additional sand was added to cause them to elevate in a manner as natural as possible. It could be seen that the shells contracted together and the foot pulled up, causing a 'rain' of sand down around the clam. The foot would be re-extended with a wiggling motion during the quiescent stage, and again the shells and foot would be contracted. No water currents were seen below the clam, but it is certain that the foot did not seem to *push* on the sand to elevate the clam. I think that the foot compacts the bottom sand to allow the grains to settle without binding up in the shell area.

ANSELL (1962) has reported the discussions in the literature regarding the mechanism whereby clams stop burrowing downward when they are 'deep enough'. Of course, one must be careful not to generalize that the behavior of even one species can be explained by a single mechanism, and certainly the behavior of a whole class cannot be explained with one parameter. FRAENKEL (1927) implies that in the solenids the correct depth is determined by fatigue, while ANSELL implies that in the venerids it is siphon extension. I can appreciate the work it would require for a long-siphoned clam to burrow to nearly the length of its siphon, so fatigue should be considered, but I believe that if these clams were dug up immediately one would find them capable of reburying themselves several more times, therefore fatigue cannot be the exclusive factor, and certainly siphon extensibility is a factor.

I exposed *Actactodea mitis* to repetitive burrowing by shaking the bucket, which caused them to be buoyed out of the sand and tipped over onto their sides, about every three minutes. Since I was after data on how many times the clams would rebury, I discarded clams that could not bury themselves in three minutes. They could dig into the sand up to the siphonal margins in 30 seconds, once they got started. I removed the stragglers (one or two clams at a time, except for one occasion with four individuals) to keep all digging clams at the same number of complete cycles. The diameter of the laggards was taken as they were removed, but no size trend was noted. The following table indicates the endurance of the 40 clams starting the test:

Number of reburials	Lapsed time, minutes	Number of clams remaining
5	22	36
10	34	31
15	45	24
20	56	19
25	68	8
30	90	5

SUMMARY

Actactodea mitis was found to be able to elevate itself in coral sand at a rate of at least nine inches in six hours. A differential in specific gravity between clam and sand, together with a sifting of smaller sand grains beneath a larger clam could aid in this movement when the sand is moved by the clam's valves and foot, or by external water action. Selected individuals could rebury themselves 30 times in $1\frac{1}{2}$ hours.

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LITERATURE CITED

ANSELL, ALAN D.
1962. Observations on burrowing in the Veneridae (Eulamellibranchia). Biol. Bull. 123 (3): 521 - 530

ARMSTRONG, LEE R.
1965. Burrowing limitations in Pelecypoda. The Veliger 7 (3): 195 - 200; 4 text figs. (1 January 1965)

FRAENKEL, G. V.
1927. Die Grabbewegung der Soleniden. Zeitschr. vergl. Physiologie 6: 167 - 220